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# Operational Conceptual Modeling in Building and Sustaining Technology Enhanced Learning Communities

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**Abstract**

This paper presents a systematic approach to building and sustaining technology-enhanced learning communities based on a conceptual model that enables the analysis and enhancement of digital platforms and tools that promote creativity and learning. Two such software systems are presented, and their usage is analyzed. Experimental results are also presented that demonstrate the effectiveness of the conceptual model in enhancing the learning experiences offered.

*Keywords:* Performativity, Communities, Learning, Creativity, Shadow Theatre, Spatio-Temporal Processes

*ACM 2012 CCS Concepts:* Human-centered computing → Collaborative and social computing → Collaborative and social computing theory, concepts and paradigms → Computer supported cooperative work

*Mathematics Subject Classification 2020:* 68U35

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## 1 Introduction

People satisfy their learning and creativity needs by interacting with other people and sharing their lives in social structures, physical or virtual. Within these structures, they usually take on different roles and share common goals and expectations. During the learning and creation process, people come into contact with each other. They also come into contact with people who are not physically present, such as manufacturers of used artifacts, people who produce the knowledge they are trying to assimilate or even people who come after them to use the products of their actions. The general concept of community can therefore be used to express the social context in which human creativity is practiced and knowledge is learned.

With the advent of digital technologies, these social contexts, the communities in which people are involved, are radically changing. The first predictions that networked computers will give rise to new social phenomena were made in the 1960s by Licklider & Taylor [1], who engaged in research and development to design and present the technologies of ARPANET, the first virtual community [2]. Today, this new landscape created by digital technologies is characterized by new qualities, new possibilities for action, new possibilities for the community [3].

The term onlife is taken from the Onlife Manifesto [4] and is used to refer to the new type of community created by modern digital technologies, the onlife communities. The main research question of this work is to explore design principles that can be applied to foster such communities and support their members in creative expression and learning. The central assumption is that the communities in question are built directly or indirectly around digital technologies. In its simplest form, a community can consist of people using a particular digital tool or platform to perform certain tasks. In a more complex case, the community can assign certain roles to its members regarding their knowledge and skills and how they contribute to the development and use of certain digital technologies in a broader social context. A very interesting special case is digital games, including serious ones [5–9].

The research reported in this paper has been developed to serve a very practical objective: how existing digital systems and applications can be better understood in order to be critically evaluated to find their shortcomings and identify their strengths so that they can be enhanced by building upon new community affordances to exploit the dynamics brought about by modern technologies. From another perspective, this critical evaluation towards enhancements that promote community building and sustenance, offers a rational explanation of the failures or successes of existing systems so that recurring patterns can be identified and analyzed. Patterns that empower users and offer guidelines for subsequently developments.

Numerous challenges arise while working on the above task: The existing situation regarding the use of certain technologies should be carefully described and analyzed, issues related to the potential of new uses or the shortcomings of current uses should be identified, new developments should be designed and put in action and finally a thorough experimentation and evaluation should be done to confirm that these new developments contribute to the community needs in terms of learning and creativity while at the same time support an intuitive use of the underlying technologies. Yet another important issue is to be able to identify when and how digital technologies are used so that, if necessary, avoid the use of digital technologies in certain situations when more traditional ways of social interaction and performance are more adequate. This is captured by the term de-design and this paper demonstrates how it can be used in a fruitful way to enrich user experience and learning opportunities.

The rest of this paper is organized as follows: Section 2 explains the rationale for the framework and offers an overview of the software that has been used in specific case studies. Section 3 presents the conceptual framework for operational conceptual modeling on building and sustaining technology-enhanced learning communities. Section 4 presents details on how the framework has been employed to design and implement specific developments on learning interventions using the digital systems presented in section 2. Section 5 presents the experimental data obtained. The results are thoroughly analyzed and interpreted. Section 6 concludes and presents plans for future work.

## 2 Background

The umbrella term that provides an integrative framework for all approaches that come from understanding of how people use modern digital technologies to create effective ways to share knowledge, experiences, and practices, develop skills, socialize and enhance traditional forms of intimacy and interaction is arguably the term virtual communities. This paper offers a new term that tries to capture important aspects of virtual communities that are brought about by the so called hyperconnected era. The new term is onlife communities. Onlife communities are linked to performativity and how theatre can be used to describe rich interactions enabled by digital technologies. They are also linked to the concept of universality and how it is related to causal relationships that can be enhanced and better presented via the use of digital tools and technologies.

### 2.1 Performativity and the link between computers and theatre

Performance is an important concept that provides a rich conceptual basis for describing how people interact with each other and with their environment. Performativity goes beyond the usual understanding of the world as a web of objects that are confined by certain properties and exhibit certain behaviors. Performativity is, in its essence, a meaningful bodily practice, a certain way of action and interaction that is informed by the conception of the reality and ultimately can transform the reality. Consequently, it is linked to rituals and other forms of entertainment and social practices [10]. Leaving aside the main premises and the theoretical justification of the validity of performativity, the meaning of this paradigm could be attributed to an intrinsic dramatic nature of human social experience [11].

Turkle & Papert [12] explain how computers can be associated with philosophy by adopting a performative viewpoint. This way, various philosophical issues can be addressed in a radical different way: not as mere texts presenting abstract ideas but as concrete things in action incorporating the interactions between different agents: *"The computer stands betwixt and between the world of formal systems and physical things; it has the ability to make the abstract concrete. In the simplest case, an object moving on a computer screen might be defined by the most formal of rules and so be like a construct in pure mathematics; but at the same time, it is visible, almost tangible, and allows a sense of direct manipulation that only the encultured mathematician can feel in traditional formal systems [...] The computer has a theoretical vocation: to bring the philosophical down to earth [12]."*

From a broader perspective, one could argue that digital technologies are updating theater and the performing arts in general, recreating the dramatic view of social life, reconstructing social spaces into stages and social life into social drama within a unified, hyper-connected setting where theater (stage drama) and real life (social drama) are merged as onlife drama. We, as human beings, participate in this hyper-connected setting and live in parallel in two realities: the virtual reality of our concepts, our language, our ideas, etc. and the physical reality of our bodies, the material conditions of our existence. Culture is the embodiment of virtual realities into physical realities (e.g., architecture, food culture, clothing, science, language, etc.) that dictate the way of life to bring forth our virtual realities. Issues of identity and the ongoing creation of reality in performative approaches adopted by social sciences and humanities reflect exactly these facts. With the so-called hyperconnectivity (i.e. the use of many systems and devices in order to always be connected to social networks and other sources of information) a new culture is emerging, or rather a metaculture that is framed around computers as a meta-medium that emulates all other media [13].

This new culture can be better understood and developed if we go beyond conceptions that focus on representations of objects and the dichotomy between the virtual and the real. The challenge is to make ourselves aware of the dramatic nature of the hyperconnected era that promotes performative interpretations within contexts that enrich reality with universal entities that follow causal rules and thus promote conscious actions and interactions.

It is important to underline here that within this new hyper-connected social context created by digital technologies, fantasy is a key notion to understand how the "blurring between the virtual and the real" is happening [4]. The important idea, as identified by Laurel [14] is causality as a way to understand reality and mindfully interact with it: *"The fact that people seek to understand causality in representational worlds provides the basis for Aristotle's definition of universality. In the colloquial view, an action is universal if everybody can understand it, regardless of cultural and other differences among individuals. This would seem to limit the set of universal actions to things that everyone on the planet does: eat, sleep, love, etc. Aristotle posits that any action can be "universalized" simply by revealing its cause; that is, understanding the cause is sufficient for understanding the action, even if it is something alien to one's culture, background, or personal 'reality' [14]."*

It is therefore important to consider the "blurring of the distinction between reality and virtuality" in the hyperconnected age [15] as directly related to the transformation of real-world objects into universal objects, according to the Aristotelian definition described above by Laurel. A real-world object or process enriched with new possibilities for interacting with people through computer hardware and software embedded in it is more understandable in terms of causal relationships, more predictable in terms of behavior, less chaotic in its responses to people's actions.

Consider any type of cyber-physical system, such as autonomous car systems, medical surveillance systems, robots, or autopilots. All these systems essentially improve real-world objects or processes with "artificial intelligence", making them more human-sized: easier to understand and interact with. Thanks to integrated digital technologies, the capabilities of such objects or processes appear more "natural" because they provide more intuitive capabilities for the people who interact with them. In this regard, the meaning of the word virtual should not be used as a synonym for artificial as in terms like virtual reality or virtual world. It has been rephrased a lot to denote potential as real as reality, but in a different way. This is exactly what Deleuze describes in his treatise on Bergsonism [16]. This potentiality, which is the essence of Deleuze's virtuality, is the key concept that allows us to explore how the human logos (reason) transforms, through causality, disconnected reality into hyper-connected states where actions and interactions significant are possible.

Furthermore, an additional significant comment made by Laurel is relevant here and it is related with fantasy and the way it works in relation to causality, offering the basis for make-believe environments: *"We need only look to works of fantasy to find obvious examples of how universalization via causality works. Actions that are patently impossible in the real world (such as a person flying) can be made believable and understandable in their dramatic context if probability is established. This fact led Aristotle to observe that in dramatic action, an impossible probability is preferable to an improbable possibility. We can believe that Peter Pan flies because of the way the potential of his world is revealed, through the way his character is established in the action, and through dramatic situations that provide him with causes to use his ability to fly [14]."*

It is evident from the above that causality is much more significant than real possibility. That is to say, reality is better understood and given meaning if it obeys causal relationships. Digital technologies enable this type of understanding if systems are properly designed and deployed so that our interactions with certain objects can clearly be attributed to certain underlying rules. As a result, an important design requirement for digital technologies is to effectively support the construction of causal mental models that can then be used to promote meaningful interactions between humans and computer agents.

At this point it is important to emphasize that Laurel maintains a rather conservative view on the applicability of her ideas although she succeeds in capturing the most intrinsic characteristics of digital technologies, the characteristics that explain their success in enabling meaningful interpretations of reality. She considers the engagement that digital systems can offer to their users from an entertainment aspect only: *"Engagement, as I use the concept in this book, is similar in many ways to the theatrical notion of the "willing suspension of disbelief," a concept introduced by early 19th-century critic and poet Samuel Taylor Coleridge. It is the state of mind that one must attain in order to enjoy a representation of an action [14]."*

This phenomenon of "willing suspension of disbelief" is often found in both dramas and computer games, where the viewer and the player, respectively, have almost identical feelings toward the characters. They may cry when watching a movie or share emotions with characters in virtual space. But, as Laurel says, "spreadsheets aren't pretend!" She argues that activity in a virtual environment must be separated from its artifacts. Presenting text, spreadsheets, databases, and other computer artifacts while manipulating them on a screen is essentially a sham compared to physical artifacts such as printed text or files in computer storage. Artifacts are as real as actors, lights, and scenery in the theater, but the rules of operation involved in presenting dramatic action and interaction are different from those involved in dealing with artifacts.

Therefore, it is important to understand that the concept of representation is key to understanding the capabilities attributed to artifacts, i.e., what they can do. Moreover, as Laurel argues, special states of being as representations influence one's feelings about them, allowing for a much more pleasurable experience than we normally experience in real life. She adds that a feature of the emotions evoked in the context of representations is that there is no pain or threat of harm in the real world.

Finally, Laurel emphasizes the playfulness of the individual when interacting with such representations and cautions against the dangers that such attitudes may carry under certain circumstances. *"Further, engagement entails a kind of playfulness: the ability to fool around, to spin out "what if" scenarios. Such "playful" behavior is easy to see in the way that people use photo editing suites and document creation software. The key quality that a system must possess in order to foster this kind of engagement is reversibility; that is, the ability to take something back. In the age of the Internet, taking something back once it is published is nearly impossible. We and our children need to understand that; fooling around is playful, but publishing is forever [14]."*

Laurel further elaborates on this distinction between the uses of computers for entertainment from other types of uses: *"This principle suggests that activities like running a nuclear reactor or launching a spacecraft – things with real potential in the real world – should be taken off the table when we talk about dramatic interaction. For example, the control system on a nuclear reactor involves many, many representations of the state and operations of various system components, but in the context of real-world consequence, these representational affordances are much more about human factors and tele-operations than they are about the pleasure of interaction [14]."*

From another perspective, however, dramatic interaction (or meaningful performance) is not only about entertainment. It is also present in other, more serious human activities, such as politics, social interaction in the workplace, education, and economic transactions. In areas where decisions and actions have very important consequences, they may not be as irreversible as in entertainmentoriented contexts, but at the same time they exhibit a distinct dramaturgy. This is an important extension of Laurel's work, facilitated by the structure developed in this paper and presented in Section 3. As mentioned, this framework uses the concept of performativity as an overarching term that connects the social context created by digital technologies with aspects related to the world of representation traditionally considered in theatrical analysis.

The following subsection presents the specific software used in the case studies undertaken to test the effectiveness of the framework in analyzing, extending, and evaluating digital systems to create and sustain living communities.

### 2.2 The eShadow tool

Shadow theater is found in many Far Eastern and Middle Eastern countries that uses flat moving puppets held between a light source and a translucent screen, usually in the form of a white cloth. It is a medium with significant educational value within the broader context of dramatic and performance arts [17]. This is due to its ability to inspire people and encourage their creativity. Children and adults in particular find their own ways to play and imitate, to create dialogues, to be inspired and to transmit their own messages, to direct, to become set designers, to sing, to gain self-confidence in breathing life into the puppets to improvise and create their own stories. They cultivate their oral language skills and develop their intelligence (multiple intelligences) in a fun way. The diversity of possibilities offered by shadow play (for example, when children play with hand shadows) has impressed people throughout history. This has made traditional shadow theater so popular in many countries over time [18]. Furthermore, the important impact that shadow theater has on children justifies its use as a learning tool. In addition to watching the shows in the shadow theater, kids can also be busy creating their own shows. They can work together in groups and each group can be assigned to different tasks of the game creation process. The most common elements of a play are: the script of the play, the dialogues, the music, the characters and the settings. Children work together to create the script and dialogue, find the right music for each part of the play, and design the puppets or scenery.

eShadow (http://eshadow.gr/) is the digital version of shadow theater [19]. It enriches traditional functionality with elements of digital technology to deliver a new way to tell dramatized and personalized digital stories. It enables the interactive production of rich media content with innovative input devices and supports online collaboration. It offers an intuitive way to set up and run scenes: the user can select the desired set objects and digital puppets and then move them with mouse movements. All movements can be easily recorded along with the user's voice. These recordings can be exported to the appropriate file formats for further editing with external video processing tools.

eShadow emphasizes the realistic simulation of shadow theater puppet movement, based on a physics engine. The realistic movement provides an explanation for the popularity of eShadow among Greek teachers and students, as revealed during several field trials and during tests with real professional artists [19]. eShadow is used in many schools to encourage project-based learning combining the arts in a wide range of school subjects from language learning, history and social studies to math, science, and computing [19–23]. The creation of such works with eShadow is based on a project-based process in three distinct phases, which is generic and linked to any media work such as film, digital game, interactive animation, etc. In particular, the phases of this process are: preparatory actions (pre-production), further development (production) of the main materials of the work, and final assembly (post-production) of a digital story. During the pre-production phase, eShadow users can create their own digital puppets using an appropriate external image processing tool or dedicated software tools that come with eShadow [21–23].

eShadow enables real-time collaboration over the Internet by staging intra-family communication scenarios for intergenerational bonding and play-based learning, as well as collaborative learning scenarios [24] between students from distant schools [19]. This is achieved through a corresponding client-server architecture. Several input devices are used to control digital puppets, including the computer mouse, a motion-sensing controller like Nintendo's Wii Remote, or any device that supports the Open Sound Control standard. Collaborative online performances are supported to record, save, and combine individual scenes into playlists. Each remote client communicates with the eShadow server (Figure 1), which coordinates between the clients so that all clients see the same scene with synchronized movements of the digital puppets.

eShadow offers an intuitive way of setting up scenes and enacting them. The user can select the desired scenery objects and digital puppets and then move them with mouse drag operations (Figure 2). All movements can be easily recorded along with the voice of the user. These recordings can be exported in appropriate file formats to be further edited with external video processing tools.

eShadow gives emphasis in the realistic motion simulation of shadow theatre's puppets (Figure 2) that is based on a physics engine. Significant importance has been given to eShadow's usability as it targets users ranging from young children to teenagers, parents and teachers. Throughout the system development, appro-

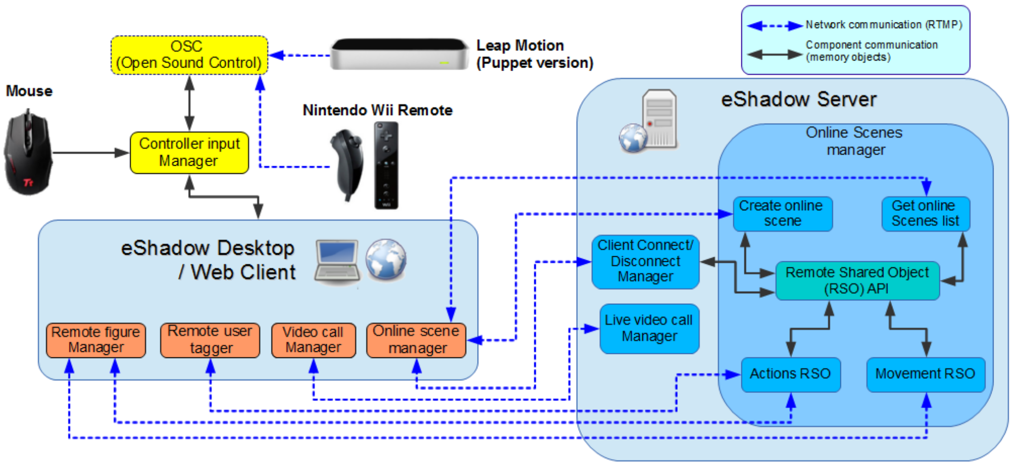


Figure 1: eShadow client-server architecture and input devices.

Figure 2: Enacting a scene with three puppets and two scenery objects (background picture and table) in eShadow.

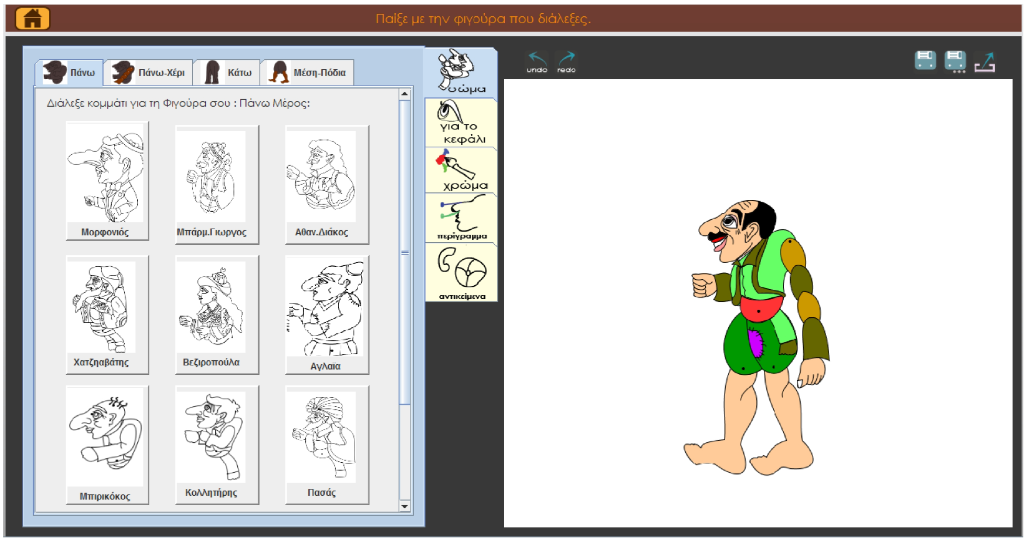


Figure 3: Remixing a digital puppet in eShadow editor.

priate design principles were adopted [25] and usability tests were conducted with real users. The results derived were then analyzed in order to extract requirements for the continuous improvement of eShadow's usability and functionality. Widely accepted methodologies were used for the evaluation of the whole system [19, 21].

A special desktop application, namely eShadow editor, enables creation of digital puppets. Significant emphasis has been given on the usability of this application as well by using similar software development methodologies [21] as in the case of eShadow. eShadow editor provides a playful environment (Figure 3) where children can remix digital puppets in many ways: by painting, changing the appearance of their faces, combine different body parts and use various accessories such as hats and hand-held objects. Digital puppets can be stored for further editing or exported to eShadow to be used in actual scenes and improvisations.

### 2.3 The ViSTPro Platform

ViSTPro is an intuitive tool for visualizing spatio-temporal processes. Such processes provide a unified model for representing different types of knowledge content, from historical events such as representations of battles and other historical events [26], to physical processes studied in Earth and life sciences, etc.

[27–29]. Because of their complexity and dynamism, such processes are difficult for students to understand using traditional teaching and learning approaches [30]. Therefore, a general approach to dynamic spatio-temporal process modeling can be used to support many educational domains and promote active and exploratory learning styles.

Interactive digital maps, in which important visualization principles are appropriate [31] and overlaid with appropriate active objects representing real-world phenomena and events, can be used to meet this need. In this way, an open research environment can be created and presented to the learner in the form of an intuitive, dynamic spatio-temporal model [30]. The learner is able to create symbolic entities, move them around and determine their interaction with other entities. In other words, in such an environment, a "visual narrative" for the unfolding of a spatio-temporal process is developed through the animation of imported, process-type-specific graphic symbols superimposed on a map. Students are familiar with this type of animation because they regularly use digital applications with similar functionality [32]. Transferring this positive experience into the context of learning is fun and expands opportunities for student engagement.

Careful design is required to effectively support spatio-temporal learning; ViSTPro uses the concept of scenarios to simulate complex spatio-temporal processes [33–36]. This concept offers a visual representation of the evolution of spatio-temporal processes. Descriptions and semantic maps play an important role in this representation; ViSTPro distinguishes between scenario creation and scenario visualization. When creating a scenario, ViSTPro supports and guides the scenario creator through the entire process. The scenario creator first chooses a name and describes the new scenario. At the same time, they define the active components of the scenario.

Scenarios include groupings, entity types, and specific entities. Groupings represent the troops involved in the battle, entity types refer to infantry and cavalry, and specific entity types can represent key figures such as warlords. The distinctive colors of each troop type and the representation of each troop type can be selected by the user, and additional symbols can be included. Some troop types are displayed larger to distinguish them from other troop types. In addition, the representation of different statuses of object types is supported, providing multiple indications for each (e.g., dead, under fire, etc.) and allowing users to create custom statuses. These elements are included in the optional map legend to facilitate the descriptive power of the presentation.

The second step in the creation process is to structure the scenario. The structural elements of the scenario include activities, sub-activities, and events.

The activities correspond to the basic units of action (Figure 4). Each activity has a name and description and may contain other activities and basic units of action (sub-activities) within which the action unfolds and visually describes the movements, actions, and interactions of the active components. Each sub-activity has several properties such as title, description, start and end time, images, actions associated with the recorded scenario and other sub-activities of the scenario. Sub-activities can include milestones or events that represent specific events. Events are identified by name, description, timestamp, and, in some cases, correlation to some subject, state, or semantic object. Thus, each scenario is modeled as a hierarchy of actions, sub-actions, and events.

Another important element of the script is the set of formations to be visualized. A formation is a group of entities considered as a whole and ViSTPro provides the necessary tools for designing formations with predefined geometric shapes (squares, rectangles, circles, polygons, etc.), different sizes, orientations, etc. Once a formation is defined, you can specify the types of entities contained in the corresponding formation, as well as their size, position, and density. You can also specify the presence and position of one or more specific entity types.

It is possible to edit specific formations using sub-activities. When creating a sub-activity, the author of the script determines which formations will be displayed, their start and end positions, and specifies the path to follow during playback of the script. In addition, several actions are provided for each formation. These actions are related to the behavior and interaction during playback.

Actions are represented by icons, arrows and other relevant graphics. A formation can change its state by moving, performing actions, or interacting with other formations during scenario playback. Thus, it is possible to redefine the state of a formation by specifying its size, shape, and density of different types of units during scenario creation, thereby changing the state of the formation.

Another important modeling primitive is graphics. A number of graphical elements are available, such as lines, arrows and other predefined elements, which are superimposed on the map during scenario creation and play an important role in the visualization of the scenario. Semantic content is provided by titles and descriptions, and characteristics such as color, size and orientation can also be defined. During the playback of a scenario, graphics can be static or moving. They can also change shape, as can the state of education.

Important aspects, such as artifacts and important locations in the environment, are addressed through process visualization. Semantic maps are used to represent and provide relevant information about these items. Semantic maps are groups of important geographic features or objects that are displayed on a

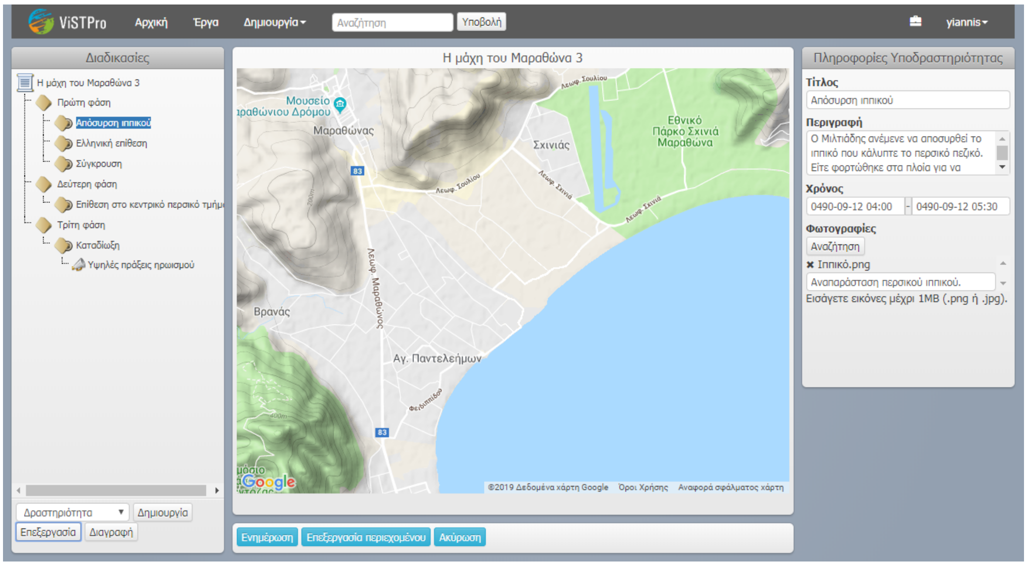


Figure 4: Structure of a spatio-temporal process in ViSTPro with its hierarchical structure (left), its visualization on top of google maps (centre) and descriptive attributes (right).


Figure 5: Scenario playback in ViSTPro.

map. By creating semantic maps, it is possible to construct semantic objects with names, descriptions and one or more images. As a result, it is possible to interact and explore the semantic content of the semantic map objects during the playback of a scenario. The semantic map can be modified by selecting certain objects and constructing a new semantic map with them. The updated semantic map can be saved under a new name for later use. The original or unique semantic map can be applied in one or more of the aforementioned cases.

During scenario playback (Figure 5), the human learning needs are satisfied by providing an account of how the processes depicted in each scenario evolved. ViSTPro adjusts the size, shape, density, and state of the different objects by appropriate interpolation. This way it is possible to control the movement of formations from start to end position and represent changes in their state. In addition, during the playback of a scenario, each action is displayed with subtitles and its description, which can be supplemented by a recording of the narration. The user can also pause during playback to view the images and relevant information recorded in the sub-activity.

## 3 The PerFECt framework

The Performative Framework to Establish and Sustain Onlife Communities is based on several key concepts, one of which is performativity. Performativity is a concept that, as Cabitza & Simone [37] state, emphasizes that all human behavior can be understood and analyzed by assuming that it is performed, so that behavior can be viewed as a public presentation of the self.

This allows us to view actions as a public presentation of the self. This is the conceptual basis for the methodological breakthrough known as the performative turn in cultural studies, social sciences, humanities and design. The word "turn" refers to the tendency to invert the ontological assumption that reality exists as itself and corresponds to a particular object, subject or configuration that exhibits certain essential properties, to the new central hypothesis that objects are partially coherent, partially coordinated performative qualities that exist through multiple situated practices.

Meaning making is an inherently social process. Knowledge is created through the actions of members of the social structure. In this respect, there is a shift toward "the active social construction of reality rather than its representation [38]." The roots of this approach can be traced to the need to move beyond the assumption that textual and symbolic representations to convey meaning.

This section presents the components of the PerFECt framework using the ideas outlined above and other concepts presented in Section 2. In particular, the specific roles that enable the creation and maintenance of onlife communities (end-users, expert-users, maieuta-designers, and meta-designers), and the interactions between these roles that lead to co-evolutionary phenomena that reflect the dynamics between community members and the tasks they perform.

As noted in [39, 40], end-users of digital systems are increasingly expected to actively participate in the use process and become creators of content and functionality. The term expert-user is used to refer to a person who is an expert in a particular field and whose primary goal is to develop the functionality of available software tools. The expert-user summarizes all of these roles, indicating people who are not professional software developers but are responsible for performing creative/authoring activities. Typically, the end-user role and the expert-user role are performed by different people and may belong to different communities. In addition, [39, 40] suggest the role of meta-designers, representing experts who create socio-technical conditions for expert-users to participate in the ongoing development of the system. Meta-designers can create open systems during design and develop them with the help of users acting as co-designers.

Another important role is that of the maieuta-designer who deals with organizational and social rather than technical issues to support the task of the expert-user, providing the social and technical conditions necessary to create new solutions with the technical means available to the expert-user. This task of the expert-user appeals to as many end-users as possible in the continuous development of the technologies available, thereby encouraging and strengthening participation, which is the main goal of maieuta-designer. The term "maieutics" is used by analogy with the method of learning of the philosopher Socrates. In other words, it is about transforming from an end-user to an expert-user, from a passive consumer of technology to an active developer.

Based on the above-described conceptualization of the user roles of meta-designer, maieuta-designer, end-user and expert-user, the PerFECt framework translates these concepts into the so-called hyperconnected context specific to modern digital technologies. This is expressed by the term onlife, borrowed from the Onlife Manifesto [4], to describe the type of community that this system seeks to describe and create. The Onlife Manifesto is the result of work carried out as part of the Onlife Initiative, a project organized and directly implemented by the DG Information Society of the European Commission in 2012. The aim of the project was to examine the extent to which digital transformation affects society's expectations for policy making. The result of this project was the Onlife Manifesto [4]. This manifesto stipulates that the emergence of digital technologies in all spheres of life will have a fundamental impact on human existence. It affects our frame of reference in several areas, including self-awareness (who we are), interaction (how we communicate), our idea of reality (metaphysics), and our interaction with reality (behavior).

The neologism onlife, taken from the Onlife Manifesto, refers to a new experience of a hyper-connected reality where it no longer makes sense to ask whether we are online or offline. In this new reality, spawned by digital technology and its ubiquity, important changes are taking place in the relationship between reality and virtuality, in the richness of information, in the interaction between humans and machines, and between humans and nature and its meaning, beyond the primacy of traditional entities.

In response to these developments, the PerFECt framework offers a term for the aggregates that emerge in hyperconnected spaces, where humans interact with other humans, as well as with machines and natural entities with enough sense of human feelings to form networks of relationships. By adopting four user roles – end-user, expert-user, meta-designer, and maieuta-designer – we want to give a certain structure to the onlife community and create a mechanism to enable rich learning experiences.

To further analyze how these user roles can be understood in their dynamics, it is important to note that they interact with each other, with digital artifacts and digital tools, forming a co-evolutionary phenomenon. Meta-designers focus on designing and delivering the most effective tools that can support the co-evolution between end-users and expert-users. Maieuta-designers facilitate the transition from end-user to expert-user roles so that end-users can embrace and contribute to the use of the digital tools available to them. If end-users are not interested or capable of the expert role, the maieuta-designer can facilitate their participation in system design by systematizing the reports of deficiencies and system bugs found by end-users and suggesting solutions that should be considered by the expert.

As a result, the four roles described above create two co-evolutionary processes. One focuses on the end-user, which means using software where there is continuous (cyclic) interaction between the end-user and the system. This is illustrated in Figure 6 (left), where three concentric cycles with arrows represent the action-interpretation cycle at the lower level, the task-object cycle at the middle level, and the community-technology cycle at the upper level. The second cycle process, shown in Figure 6 (right), occurs in a similar way. This refers to the use of software components as components of a constantly evolving system from the perspective of experts and users. This process corresponds to three

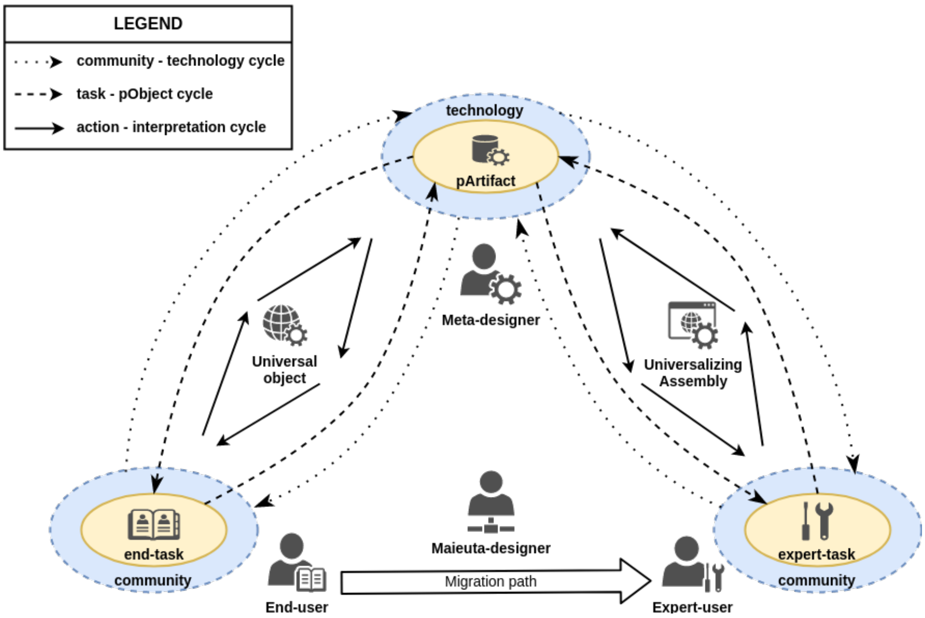


Figure 6: Main components of the PerFECt framework.

other concentric cycles of the same type: action-interpretation, task-object, and community-technical level.

The internal interaction cycle in each coevolutionary process refers to actions that are interpreted by the other party (software or user) (triggered by the corresponding user or software). The central task-object cycle refers to the co-evolution of the user's tasks and the corresponding artifacts within the boundaries of the system. Finally, the outer community-technology loop summarizes the idea that the whole environment (community) in which users work evolves along with the technology that supports that environment.

Before describing the two processes of end-user and expert-user co-evolution in more detail, it is necessary to introduce the notion of universality. This notion refers to the mixture of machines and physical objects that generalize the concept of software and tools within a hyperconnected landscape. Universality addresses the problem of causality in digital representations, as we have already seen by referring to Brenda Laurel's related idea in Computer as Theater book [14].

As a result, we can say that a universal object is an artifact that allows its user to manipulate and understand it effectively, that is, it represents itself in a meaningful and intelligible way through certain connections relating to certain interpretations. A universal object can be made to act to produce a certain effect because its contingent interpretation enables a human agent to understand what will happen if the object is manipulated in a certain way. It can also produce the desired effect in the context in which it is used because the response to a particular operation is predictable. In this respect, the essence of digital technologies is the transformation of any kind of object into universal one. Universal objects are considered as core elements of the PerFECt framework, where end-users use them directly and expert-users contribute to their evolution (as universalizing assemblies).

End-user needs evolve with the use of a particular technology, which means that system designers must also support the evolution of systems to adapt to and meet the evolving needs of end-users. Similarly, the needs of expert-users also evolve. This evolution is part of the co-evolution phenomena shown by three co-eccentric cycles on the left and on the right of Figure 6 were first described in [41].

Let us look more closely at the phenomenon of co-evolution around universal objects, as shown in the left part of Figure 6:

- At a higher level, there is the co-evolution cycle between community and technology, which means that the relationship between people and technology is dynamic and evolves as people working with a particular technology evolve and learn how to do certain things, and as a result of this evolution, their expectations and conceptualizations about the available technology change, leading to an evolution of the technology itself, which triggers further evolution of the community of end-users. This overarching co-evolutionary cycle encompasses people's motives, i.e., their needs and how they satisfy their needs through their activities. By providing new opportunities for interaction, the technologies used change the habits of end-users, and this means that social and work organization evolves with the use of certain technologies.

- At a lower level, there is the cycle of coevolution of tasks and artifacts, which refers to the tasks that end-users can perform with a particular version of a system and the corresponding artifacts that they manipulate or use during their work. Thus, at this level, end-users articulate their behavior toward specific goals that form a cause-and-effect chain to track upper-level motives. Moreover, in many cases, the use of certain artifacts to support end-user tasks suggests new possible tasks, and these new tasks imply that new artifacts should be created.

- At the lowest level, there is an interaction cycle in which end-users are expected to perform certain operations in order to effectively use the available technological features. Such interactions require a certain interpretation of their actions in order to effectively use the available functions. This cycle at the lowest level could thus be conceptualized by successive materialization and interpretation that constitute meaningful actions that support and trigger the upper levels of the co-evolution phenomenon.

At the center of the three end-user cycles (left part of Figure 6), the PerFECt framework proposes the concept of universal object, a concept that generalizes the concept of software and is based on the concept of universality presented earlier. Such universal objects can be the result of expert-user work, as described below, to meet the evolving needs of end-users within the broader context provided by the PerFECt framework.

The co-evolution cycles that address the role of the expert-user (right part of Figure 6) are built around the concept of universalizing assembly. This is a complementary concept to the concept of universal object. A universalizing assembly is essentially a synthesis of performative artifacts (pArtifacts) that enables the creation of universal objects that support end-user tasks. Consequently, the role of expert-users is to enable this universalization of simple objects by using the available tools in the form of performative artifacts (pArtifacts) to accommodate the incorporation of the idea of performativity into digital technologies.

Performativity emphasizes the relationship between people and the artifacts they create, which is triggered by social interaction and continually reestablishes the bonds that hold society together as a whole. Niedderer [42] offers an interesting concept to capture this idea and connect it to the purposeful and mindful use of physical objects: the concept of the performative object, which is a particular kind of design object to facilitate a mindful awareness of physical and symbolic social actions and their consequences.

Considering that performative objects are design objects, the term performative artifacts is used in a broader sense in the framework presented here: All artifacts exhibit some degree of performativity, usually captured by their affordances, i.e., indications of how an object should be used, usually given by the object itself or its context. However, the latter term does not explicitly refer to mindfulness as a goal in the design process. In this regard, the term "performative artifact" is used here to capture the idea of intentional design for social interaction, to create and sustain social bonds, and to call for symbolic social actions that recreate the social contexts in which we live.

As a final note on how the PerFECt framework can enable the use of digital technologies in rich social contexts and provide the means to foster learning and creativity, the idea of de-design should be emphasized. According to Cabitza [43], de-design represents the idea that omitting features from a design is as critical to the success of a system as positively including them. This is related to the fact that each feature both enables and constrains interactions with and through the artifact, and that what is omitted can potentially be even more important than what the designers intentionally added. This is not to be understood as an anti-theoretical or thoughtless attitude, but rather as disciplined, intentional, thoughtful, purposeful, and effective doing nothing.

De-design contrasts with the positivist stance of traditional design by recognizing that a designer can unhinge the effective way people work and act, making it impossible for them to take advantage of opportunities to create more diverse, tailored, and appropriate processes on the ground than those designed at the abstract level of the traditional design process, and neglecting different interpretations of the information that must be considered in user practices, thus also disregarding the creative power of ambiguity.

In the section 4 below, concrete examples will show how de-design can be used to find new ways of interacting with digital artifacts and to offer new uses and improvements of learning and creativity platforms and tools.

## 4 Usage of the PerFECt Framework

### 4.1 Digital cultural heritage installations with eShadow

Using the PerFECt framework, user concepts and roles, understanding the use of tools such as eShadow can be placed in a broader context that takes into account the rich social interactions that can be encouraged towards creating onlife communities. In particular, eShadow can be seen as a representative tool for building a community (in the field of cultural heritage and learning) that brings together the following:

- Software developers who support the software and provide further enhancements to meet user needs.
- Puppeteers who prepare materials, such as puppets, which can be used to support other creators, those who use the platform to develop animations and stories on various themes.
- Storytellers who use content provided by other creators to develop digital stories.

Using the user role terminology introduced in section 3, the above categories of participants in an eShadow-based community can be rephrased as follows:

- The software developers supporting eShadow and implementing further enhancements are the meta-designers of the PerFECt framework. As meta-designers, they are expected to provide an open system that can evolve (co-designed) by users. To make this possible, eShadow provides an open architecture based on json files to allow the creation of content such as digital puppets.
- Puppet makers who develop digital puppets are described as expert-users by the PerFECt framework. They respond to the needs of end-users by using the open system capabilities provided by meta-designers to develop new reusable materials.
- Storytellers using eShadow to develop digital stories are what the PerFECt framework calls end-users. They essentially use the creations of expert-users in the form of universal objects, i.e., digital artifacts that exhibit a certain behavior that simulates the behavior of traditional puppets with all the causality that comes from the presence of gravity.

In addition to the aforementioned roles, which are directly related to eShadow as a tool that simulates and extends a traditional creative environment, the PerFECt framework introduces another (fourth) user role: maieuta-designers. This role makes an important contribution to the formation and support of an on-life community that focuses on social conditions to support the meta-task of the expert-user and the transition from the role of the end-user to the role of the expert-user. This transition and support of expert-user activities is essentially a learning process that takes place within a social context (user community). In the case of eShadow, a typical function of maieuta-designers is to organize workshops where eShadow users can be trained in understanding and using digital puppet representations and learn how to use existing image processing tools to develop their own digital puppets [20] or remix existing puppets [21] to suit their specific needs.

After the successful implementation of this approach in many primary and secondary schools, with very interesting results demonstrating the educational potential of such technologies and their importance in reconnecting the younger generation with their cultural heritage, the need to use traditional puppets before digitizing them was identified as a learning activity of great pedagogical value, especially for young children who need it to develop their motor skills. In addition, there was a need for the support of unskilled users to participate in the process of preparing the digital puppets using image processing software. Using the terminology of the PerFECt framework, this was a situation where the maieuta-designers collaborating with end-users revealed the need to communicate with meta-designers to request the development of a new generic component that would allow end-users to adopt a new way to work to become expert-users (i.e. puppet makers).

The result of this intervention was the design of ePuppet, a mobile application to facilitate the digitization of two- and four-piece puppets. Assuming a traditional puppet has already been made, its parts can be placed on a flat surface with a constant color background so that the ePuppet app can be used to take a picture of the parts, aligned with predefined templates, one for two-piece puppets and one for four-piece puppets. Detailed steps followed by a user using ePuppet [22, 44] include providing an appropriate name for the new puppet, selecting the appropriate model (if it is a two- or four-part puppet) and activation of the mobile phone camera, aligning the puppet parts to take a proper photo, removing the background and final production of the digital puppet. The app creates all the files needed for the digital version of the puppet to be used in eShadow and lists the new puppet in the folder area of the mobile app.

Beyond that, and in addition to using the PerFECt framework to invent new ways to create digital puppets, there is a very interesting aspect of how eShadow interprets the PerFECt framework and sheds new light on its applicability in the design of collaborative learning experiences with the idea of de-design [43]. De-designing evokes the idea that skipping and omitting features in a design is as crucial to the success of a system as positively incorporating them. This is related to the fact that each function both enables and constrains interactions with and through the artifact. What's left of it may be even more important than what the designers intentionally put into it. It is a disciplined inaction that is intentional and transcends traditional design approaches by providing opportunities for alternative interpretations of information that must be considered in user practices and recognizing the creative power of ambiguity. The relevance of de-design for learning and creativity is therefore obvious.

eShadow follows a de-design approach and takes the idea of universality as used in the PerFECt framework with the underlying concept of causality and uses it beyond digital technologies to describe a human body (or a constellation of human bodies) following certain rules. This way, the notion of universality is generalized as well as the notion of universalizing assemblies (Figure 6) to consider any type of object that can follow known rules and the corresponding constellations of such objects.

Inspired by the PerFECt framework, this approach goes beyond producing digital stories with eShadow and results in real-time performances that enable creative improvisation and interactions between participants and digital puppets using projection mapping techniques. In this way, it is possible to use digital shadow theater in new forms of learning experiences that are better suited to specialized installations in informal learning contexts such as science fairs and exhibitions, museums, etc. Two specific examples of such installations were developed on themes related to important historical events, namely the Battle of Crete during World War II (trial 1) and the Greek revolution in 1821 (trial 2).

Before entering the installation hall of the first trial, visitors had the opportunity to get historical information about the events of the Battle of Crete with detailed maps of the battle using ViSTPro. After this introductory phase, visitors entered the installation hall. The installation used projection mapping to present distinctive photos and videos of the events that unfolded during the battle. Using black light theater technology, the invasion of German paratroopers was shown as well as their fight with local volunteers with mostly primitive weaponry. Also using projection mapping, the eShadow was used to show German soldiers fighting Greek volunteers. After the performance, visitors had the opportunity to experience the events through bodily interactions with the digital puppets. At the end, they were asked to complete the Usability Evaluation Questionnaire (UEQ) [45]. A total of 14 questionnaires were completed. The results are presented in the next section and compared with the results of the second installation described below.

The second installation was based on a local legend about the death of Greek fighters that defended the Fragkokastelo castle against the Ottoman army. They all died in the battle. Legend has it that their shadows appear around the castle every May and can be seen very early in the morning, weather permitting. On the basis of this legend that is well combined with the use of shadows in the representation of these historical events, an installation was developed that included three scenes:

- The first scene used projection mapping techniques to project various visual effects around the walls of the installation hall, accompanied by appropriate music, immersing the participants and transferring them to the atmosphere, time and space in which the historical event.

- The second scene used eShadow back projected on a large white sheet as a cinema screen where the protagonists of the historical event were shown and talked with the details of the historical event.

- The third scene used black light theater techniques with the participation of students from collaborating schools to synthesize the historical event and link it to the Greek Revolution of Independence of 1821 in the context in which the event took place.

After the show, visitors were invited to interact with the eShadow puppets who improvised the movements using various props. Materials were also offered to make their own paper puppets. They were then able to digitize their creations with ePuppet. Once the puppets were digitized, participants could upload them to eShadow and use them for short improvisations.

At the end of the activity, visitors were asked to complete the same questionnaire as during the first installation (i.e. the Usability Evaluation Questionnaire – UEQ). A total of 15 questionnaires were completed. The results are presented in section 5 and compared to the results of the initial installation.

### 4.2 History teaching and learning with ViSTPro

The ViSTPro platform provides functionality that can be analyzed through the concepts of the PerFECt framework: it encourages the active exploration of spatio-temporal processes in the form of rich scenarios prepared by educators and offered to learners via a web player. Playing a scenario consists of plotting formations, movements and interactions on Google Maps. In this way, learners interact with graphical entities in an intuitive way. In contrast, traditional learning methods depend on a painful and difficult process to develop abstract mental images without direct mapping of the real world. In addition, the platform allows learners to ask questions and receive personalized explanations. Thus, learners can observe and actively intervene in the representation of the evolution of processes in space and time. In addition, ViSTPro can offer learners new learning opportunities if they are allowed to use the functionality initially offered to teachers (scenario creation). In other words, students can be supported to act as creators of their own scenarios and thus become expert-users of the terminology of the PerFECt framework. This is an option that clearly demonstrates the applicability of the framework's concepts to foster learning communities and facilitate a process of transformation from end-users to expert-users.

Using the concepts and user roles of the PerFECt framework, the use of software platforms such as ViSTPro can be placed in a broader context that takes into account the rich social interactions that could be encouraged to establish onlife communities. In particular, ViSTPro can be considered a representative tool for building a learning community in the field of cultural heritage in general and history education in particular [46, 47] which brings together:

- software developers who support the software and provide further enhancements to meet user needs,
- teachers who prepare animations of historical events, i.e. scenarios that represent the corresponding space-time processes in ViSTPro, together with semantic maps and digital material explaining the details of the animated events, and
- students use the scenarios prepared by the teachers to deepen their knowledge in the animated historical events in a personal way.

Using the user roles described by the PerFECt framework, the above categories of participants in a ViSTPro-based learning community can be presented as follows:

- The software developers who support ViSTPro and make further improvements to meet the needs of teachers and students are the meta-designers of the PerFECt framework. As meta-designers, they are expected to provide an open system that can evolve (co-designed) by its users. To make this possible, ViSTPro offers several possibilities to use different types of media, offering the necessary functionality to integrate digital material from a wide variety of sources. In addition, it provides a flexible authoring environment as a means to support experienced users who wish to develop new scenarios, animate new historical events or provide alternative views to already described events with existing scenarios. Finally, ViSTPro is also open when it comes to creating semantic maps that provide semantic information about man-made objects and physical formations on Google Maps. Semantic maps can be used in script reading to provide important semantic information that allows deeper understanding of animated events.
- Scenario writers (e.g. teachers, but also historians or even students who want to engage in activities to creatively apply their historical knowledge) who create scenarios in ViSTPro are supported by the PerFECt framework described as expert-users who address end-user needs - users who use the capabilities of open systems offered by meta-designers to develop new components in the form of universal arrangements of objects digital, which are then used by end-users in their learning tasks. That's exactly what teachers are meant to do with ViSTPro: use its features to develop spatio-temporal process scenarios that represent significant historical events. These scenarios capture knowledge of relevant historical events as well as knowledge of instructional content so that effective scaffolding can take place, allowing

students to develop their historical knowledge in a rich learning environment that supports social interactions and learning.

- Students using ViSTPro to see scene animations (using the playback functions) are what the PerFECt framework calls end-users. They essentially use the creations of expert-users in the form of universal objects, i.e., digital artifacts that represent causality within and between historical events to make historical knowledge more understandable.

In addition to the roles mentioned above, which are directly related to ViSTPro as a tool for writing and reproducing spatio-temporal processes, the PerFECt framework introduces another (fourth) user role: maieuta-designer. This is an important role that makes a vital contribution to the formation and support of an onlife community. In particular, maieuta-designers address social conditions to support the meta-task of the expert-user and the transition from the role of end-user to the role of expert-user. This transition and support of expert-user activities is essentially a learning process that takes place within a social context (i.e., the user community). In the case of ViSTPro, as described in section 5.2 that presents the evaluation of the platform, the need for a maieuta-designer arises in a completely natural way from the use of the tool in real learning situations when students express the desire to create their own scenarios (i.e. go beyond the role of the end-user to the role of expert-user) and thus learn more about the historical events they study.

Furthermore, educators also express their belief that students can learn better when engaged in role-playing tasks of expert-users, creating their own portfolio of digital artifacts that can help them express their creativity and provide insights and motivation to find more information on the historical events studied using digital sources. Consequently, this approach is directly related to inquiry-based learning and, more importantly, to constructionism: the theory of learning which states that students learn best when they construct things [48].

## 5 Experimental Results

### 5.1 Digital cultural heritage installations with eShadow

The experimental evaluation of the digital cultural heritage installations combining digital technologies and traditional arts to offer a mixed reality experience within the context of informal learning settings, employs an appropriate evaluation tool, namely the User Experience Questionnaire (UEQ) [45]. This is the

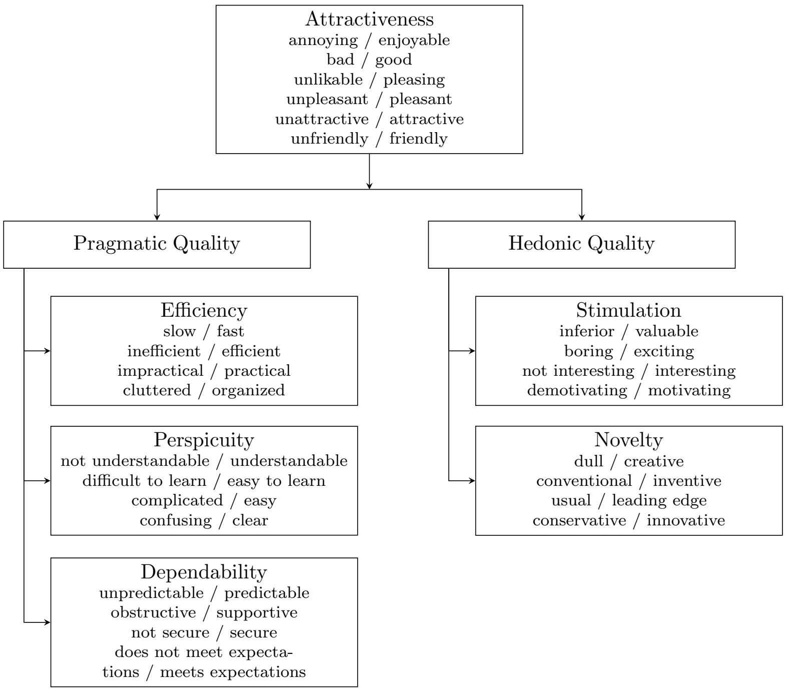


Figure 7: User Experience Questionnaire scales and corresponding questions.

questionnaire used in both trials described in section 4.1. A total of 14 questionnaires were collected from the first trial and 15 from the second one. Respondents were both adults and children that participated in each trial. Filling the questionnaire was a voluntary activity after the actual experience during each trial.

The UEQ contains 6 scales within which its 26 questions are categorized: Attractiveness measures the overall impression of the product; Perspicuity measures how easy is to get familiar with the product; Efficiency refers to how easily the users can solve their tasks; Dependability evaluates if the users feel in control of the interaction; Stimulation measures how exciting and motivating is it to use the product; Novelty addresses the innovative and creative aspects of the product and if the product catches the interest of users. Attractiveness is a pure valence dimension. Perspicuity, Efficiency and Dependability are pragmatic quality aspects (goal-directed), while Stimulation and Novelty are hedonic quality aspects (not goal-directed). The scales and the questions corresponding to each one of them are presented in Figure 7. All questions are expressed in 7-point Likert scale.

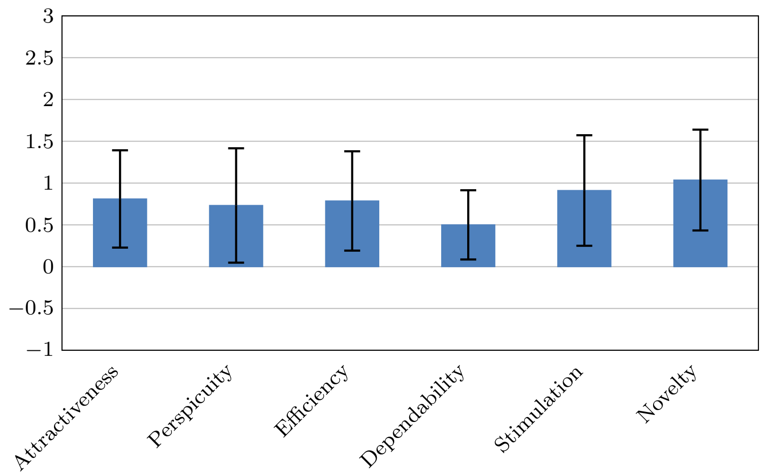


Figure 8: The mean value and standard deviation for the six scales of the User Experience Questionnaire from the first trial.

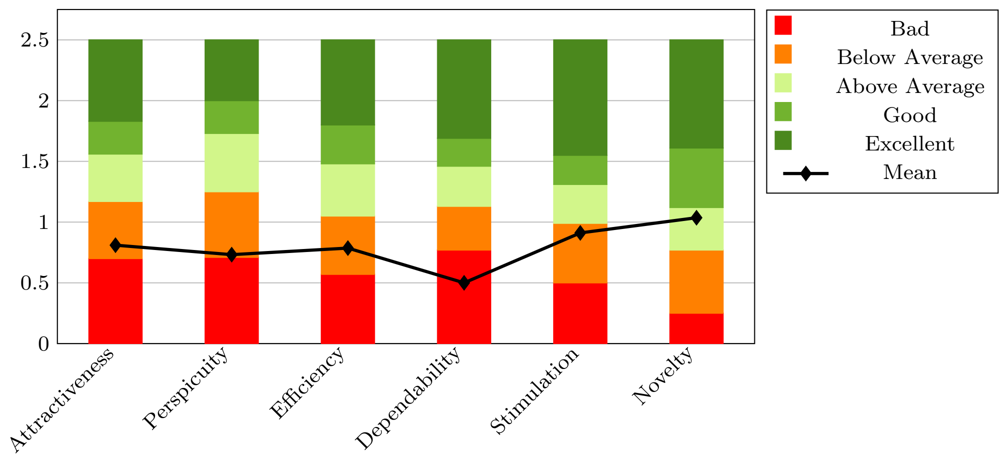


Figure 9: Comparison of first trial results against the benchmark of the UEQ.

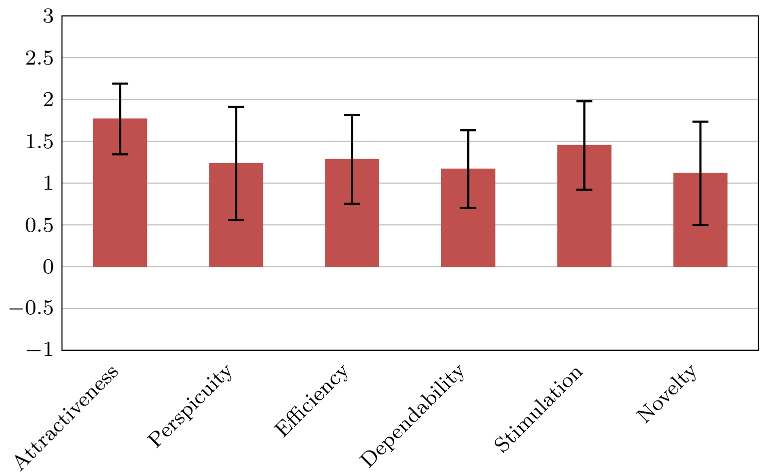


Figure 10: The mean value and standard deviation for the six scales of the User Experience Questionnaire from the second trial.

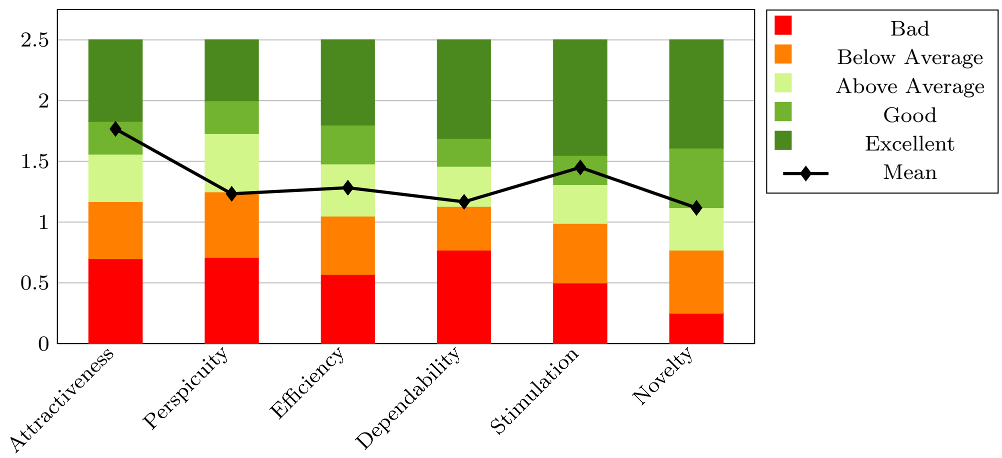


Figure 11: Comparison of second trial results against the benchmark of the UEQ.

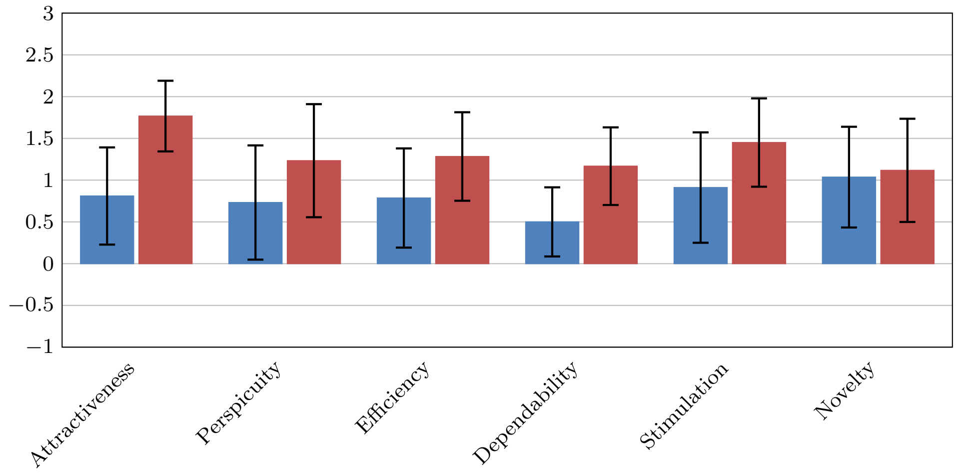


Figure 12: Comparison of UEQ scale results between the first (blue) and second (red) trials.

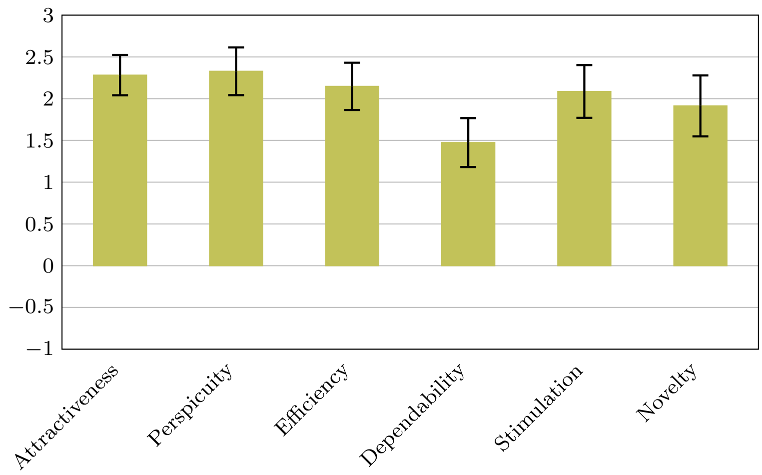


Figure 13: The mean value and standard deviation for the six scales of the User Experience Questionnaire from the ViSTPro trial on teaching local history (Battle of Crete, 1941).

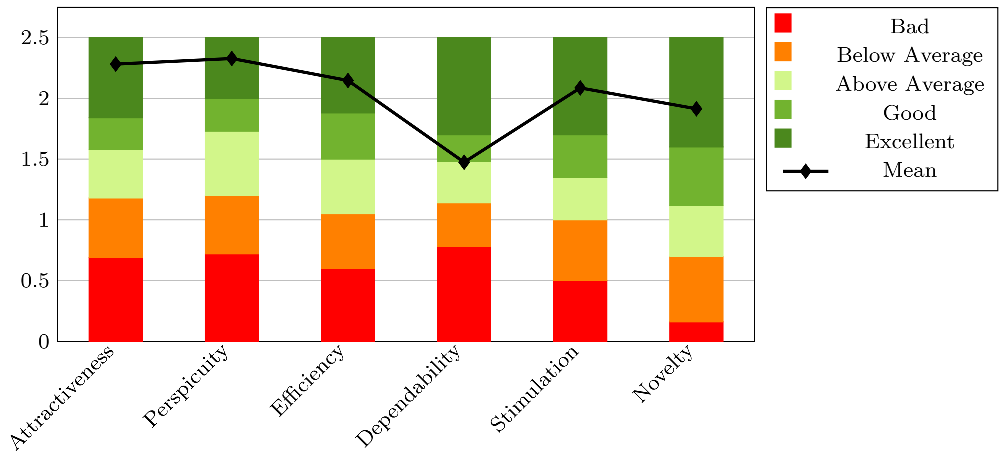


Figure 14: Comparison of the ViSTPro trial results against the benchmark of the UEQ.

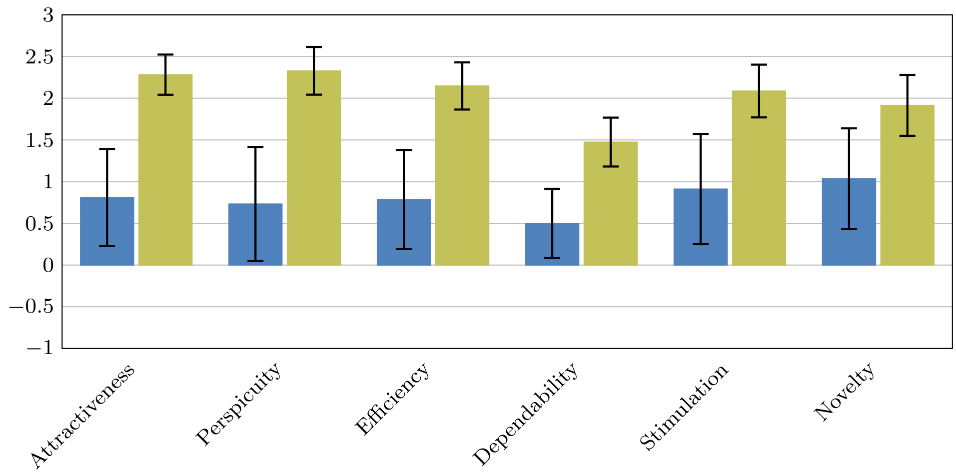


Figure 15: Comparison of UEQ scale results between the eShadow (blue) and ViSTPro (olive) trials on teaching local history (Battle of Crete, 1941).

| **UEQ Scale** | **Alpha value** | **Characterization** |
|---|---|---|
| Attractiveness | 0.0154 | Significant Difference |
| Perspicuity | 0.3166 | No Significant Difference |
| Efficiency | 0.2315 | No Significant Difference |
| Dependability | 0.0455 | Significant Difference |
| Stimulation | 0.2231 | No Significant Difference |
| Novelty | 0.8556 | No Significant Difference |

Table 1: Alpha values of UEQ Scales comparing the results of the first and second trials.

| **UEQ Scale** | **Alpha value** | **Characterization** |
|---|---|---|
| Attractiveness | 0.0002 | Significant Difference |
| Perspicuity | 0.0005 | Significant Difference |
| Efficiency | 0.0008 | Significant Difference |
| Dependability | 0.0013 | Significant Difference |
| Stimulation | 0.0063 | Significant Difference |
| Novelty | 0.0342 | Significant Difference |

Table 2: Alpha values of UEQ Scales comparing the results between eShadow and ViST-Pro trials on teaching local history (Battle of Crete, 1941).

Figure 8 presents the overall results from the first trial. The mean value of all six scales is positive. The comparison of the scores with the standard benchmark of UEQ is shown in Figure 9. Following the first trial and taking into account that most of the scales (5 out of the six) were "below average" in comparison with the UEQ benchmark, several enhancements were identified based also on free text feedback of the participants. The main issues for improvement addressed the overall organization of the installation and not so much the software features per se. Furthermore, it was decided to offer more time to participants and appropriate triggers to use the software more so that they could better understand its features and innovative approach to promote creativity and learning. Furthermore, during the second trial, the participants had the opportunity to create their own puppets, digitize them and use them from the eShadow tool.

During the second trial 15 UEQ questionnaires were collected. The results are shown in Figure 10. The comparison of the scores with the standard benchmark of UEQ is shown in Figure 11. A considerable improvement with respect to the first trial is clear: All scales' scores are above average. Attractiveness and Stimulation are within the "good" range.

Figure 12 compares the results between the first and the second trial while Table 1 shows the results of a t-test to check if the UEQ scales' means of the two trials differ in a statistically significant way in comparison with one another. As default an Alpha-Level of 0.05 has been used on the results of this t-test. A significant difference is, thus, drawn for attractiveness and dependability scales.

As it is evident from the results presented, the proposed approach effectively combines digital technologies and interactive graphics to renovate shadow theatre tradition and offer a creative digital platform in tune with current trends of learning pedagogies. Beyond formal learning settings, eShadow can be effectively combined with mixed reality technologies (project mapping) to offer experiential learning experiences in information learning settings. As it is documented from the results reported, this approach can be engaging for participants if carefully designed installations are employed that immerse the participants and provide them space and time to experiment by themselves with the software, developing their own creations, see them animated and use them in eShadow.

### 5.2 History teaching and learning with ViSTPro

The evaluation of ViSTPro was carried out in comparison with the use of eShadow within the context of the first trial reported in the previous section that addressed the historical events that took place during the Battle of Crete in 1941. In particular, the participants had the opportunity to learn about the events using specially developed ViSTPro scenarios and then attend the eShadow installation as well. The same questionnaire (UEQ) was used for both ViSTPro and eShadow installation. The events presented span several days of historical time and their presentation exploited the advanced features of ViSTPro to provide the necessary information about their time structure along with appropriate animations and presentation of semantic information on top of Google maps. Students were guided through the process of scenario authoring as well, thus taking the role of expert-users and being able to study the underlying historical events in more depth.

During the trial 29 UEQ questionnaires were collected. The results are shown in Figure 13. The comparison of the scores with the standard benchmark of UEQ is shown in Figure 14. All but the Dependability scale are characterized as Excellent. The Dependability scale is characterized as Good.

Figure 15 compares the results between the ViSTPro and eShadow trials while Table 2 shows the results of a t-test to check if the UEQ scales' means of the two trials differ in a statistically significant way in comparison with one another. As default an Alpha-Level of 0.05 has been used on the results of this t-test. A significant difference is, thus, drawn for all UEQ categories with ViSTPro usage is proved to be much more effective in all scales.

As it is evident from the results presented, the proposed approach on teaching history via spatio-temporal process authoring and visualization effectively combines digital technologies and interactive graphics to offer a creative digital platform in tune with current trends of learning pedagogies within a performative framework informed by the PerFECt framework.

## 6 Conclusions and future work

This paper studies and analyzes the use of modern digital technologies to promote creativity and learning within rich social contexts with the aim to describe and validate a framework that enables ICT experts collaborate with the users of their technologies in order to address their needs in a way that is informed by current developments in fields related to computer supported collaborative work, participatory design and end-user development. This is achieved by elaborating the PerFECt framework and presenting two specific case studies to demonstrate its use. Both case studies include an analysis of the underlying software, implementation of specific enhancements and their subsequent evaluation.

The PerFECt framework builds on previous work related to the so-called performative turn in design that embraces the concept of performativity emphasizing the fact that all human practices are performed, in contrast to the ontological premises that reality corresponds to specific objects. In this respect, knowledge is created through the actions of the members of a social structure. This line of work is combined with previous research on Human Computer Interaction that links computer systems to theatre as a way to explain how computer systems exists and evolve as worlds of representations that enable their users to produce effects in the real world by manipulating the corresponding digital representation or artifacts. This way of interacting with reality, brings forth the concept of universalization, a way to explain the reality by reference to cause-and-effect relations and changing the reality by manipulating such relations.

An important aspect that is underlined by parts of the work on this paper is the concept of de-design, i.e., the idea that omitting and leaving out features from a design is just as critical to the success of a system as it is including them positively. This is connected to the fact that any feature does both afford and constrain interactions with and through the artifact, what is left out of it has the potential to be even more important than what designers put in it on purpose. This is a disciplined inaction that is intentional and goes beyond mainstream design approaches by offering opportunities for different interpretations of the information that need to be considered in user practices, and recognize the creative power of ambiguity. The relevance of de-design to learning and creativity, is thus evident.

The PerFECt framework that integrates and systematizes the above concepts in order to enable the analysis of how onlife communities are established and evolved, how they can be enhanced and how the digital tools and platforms that they use can be analyzed, extended and enhanced. The term onlife that is employed is borrowed from the Onlife Manifesto and reflects the new reality that is brought about by current developments in ICT where people are nowadays always online, i.e., interacting in one way or another with digital systems including systems that are pervasive or embedded and thus not directly visible when interacting with physical or artificial entities.

The first case study employing the PerFECt framework refers to the digital cultural heritage domain and employs the eShadow tool. The tool provides animation features inspired by traditional shadow theatre, and its design and use are informed by the PerFECt framework to develop mixed reality installations that combine digital technologies with traditional arts and demonstrate the applicability and effectiveness of the de-design concept of the PerFECt framework as well. In particular, by careful de-design it was possible to invent a new way of using the tool by combining projection mapping and body shadows in an interactive way as well as using analogue puppet making to develop digital puppets via a specialized tool, ePuppet, that was the result of the analysis and enhancements undertaken. Following a careful experimentation, it was possible to validate that eShadow renovates shadow theatre tradition by employing Internet technologies and interactive graphics to offer a creative digital platform in tune with current trends of learner-centered pedagogies. Beyond formal learning settings, eShadow can be effectively combined with mixed reality technologies to offer experiential learning experiences in information learning settings. This approach can be extremely engaging if carefully designed immersive installations are employed that enable participants to experiment by themselves with the software, developing their own creations, see them animated and use them in eShadow.

The second case study refers to how the PerFECt framework promotes creativity and learning in history teaching and learning. It employs the ViSTPro platform for the visualization of spatio-temporal processes. This line of work employs the concepts of the PerFECt framework and in particular the specific user roles of the framework: maieuta-designers, end-users, expert-users and meta-designers. The use of the maieuta-designer role, reveals a critical contribution in framing and supporting an onlife community. In particular, maieuta-designers are addressing the social conditions for supporting the meta-task of expert-users and the transition from the end-user role to the role of expert-user. This transition and support of expert-users' tasks are essentially a learning process that takes place within a social context (i.e., the community of users). In the case of ViSTPro, the need for maieuta-designers emerges very naturally from the use of the tool in actual learning situations when students express their desire to develop their own scenarios (i.e., go beyond the end-user role toward the expert-user role) and thus learn deeper about the historical events they study. These enhanced learning results are documented by comparing ViSTPro with eShadow in engaging students in learning interventions that address a specific historical event, the Battle of Crete in 1941.

The results obtained in this paper are actively extended and further developed to promote the gamification of onlife communities with the context of the GAME IT project to offer more engaging learning experiences and address needs of special target groups including students with low school performance. This work applies the principles and concepts of the PerFECt framework on extending the Coursevo eLearning platform with a system of rewards, points and badges along with its existing certification system. More details about this work and the corresponding design and implementation can be found at [49]. Another domain of extending the work reported in this paper refers to establishing learning communities on principles of computer programming and algorithms employing visual representations of food recipes. This approach is titled Cooking STEAM to signify the linking between STEM education and the art of cooking as well as with the arts of music and drama. Cooking STEAM is also linked to cultural awareness and social inclusion. More details about this line of work and its current status can be found at [50]. This work will be further expanded to focus on learning communities for mathematics, within the context of the M2-Cm project.

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